Journal of the Lepidopterists' Society
36(4), 1982, 269–278

FLIGHT PATTERNS AND FEEDING BEHAVIOR OF ADULT *MILIONIA ISODOXA* PROUT AT BULOLO, PAPUA NEW GUINEA (GEOMETRIDAE)

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ABSTRACT. At Bulolo, daily flight activity of adult *Milionia isodoxa* commenced between 0600–0630 h when the moths began moving from hoop pine (*Araucaria cunninghamii* Ait. ex D. Don) plantations to adjacent feeding areas (the females to blossoms and the males usually to sites along streams and roads). The numbers of males at the feeding sites reached a peak between 0800–0915 h and by 1030 h most had returned to the plantations; females usually returned towards 1200 h. Field observations suggested that atmospheric conditions influenced flight behavior of the moths but no direct relationship was found.

Adults feed on floral nectar and the males presumably supplement their diet with solutes contained in wet sand, mud, animal dung and carrion. Males preferred to feed at the decomposing bodies of the toad, *Bufo marinus* Linnaeus, and at fresh cattle dung. A few males fed at dried toad bodies and at dry dung by moistening the surface with a droplet of anal liquid which they then imbibed. Observations suggested that odor was important in aggregating males at feeding sites, although some visual stimuli may be involved.

Studies in Papua New Guinea on the taxonomy, distribution and biology of *Milionia isodoxa* Prout, an endemic defoliator of hoop pine (*Araucaria cunninghamii*), were reported by Wylie (1974a, b, 1982). Only brief references were made there to studies of adult populations of this insect. The majority of adult Geometridae are nocturnal, but the adults of *M. isodoxa* are day flying (Wylie, 1974b) and are rarely attracted to light at night. They are seldom found far from where their larval host plant, *A. cunninghamii*, occurs and no long distance migratory patterns have been observed. Females feed almost exclusively on floral nectar, a habit common in Lepidoptera (Norris, 1936). The males, on the other hand, appear to feed primarily on solutes contained in wet sand, mud, animal dung and carrion, and are frequently seen in large groups at such sites. At Bulolo, the feeding sites for each sex were usually widely separated (several hundred meters or more) and the normal sex ratio of 1:1 was approached only in collections made within the plantation canopy (Wylie, 1974b). Studies of the daily movement of adults to and from their feeding areas and the feeding behavior of the males, carried out at Bulolo during the period April 1968 to April 1970, are reported below.

Materials and Methods

Five sites regularly frequented by adult *M. isodoxa* within and adjacent to hoop pine plantations were chosen as observation stations.

FIG. 1. Feeding site (station 2) at Bulolo. Plates of "attractants" used in the food preference study are shown. Margin of hoop pine plantation is visible on the left and natural forest on the right.

Stations 1, 2 and 4, each approximately 50 m^2 in area, were situated at nearly 1 km intervals along an unsealed road, 1 and 2 being at shallow creek crossings (Fig. 1) and 4 at a cattle grid. These three stations were in the open and received direct sunlight during most of the day. Station 3 (area 300 m^2) extended nearly 50 m along both banks of a shallow stream, the margins of which were, in parts, closely bounded by secondary vegetation and received patchy sunlight. Station 5 (area 50 m^2) was located beneath the plantation canopy (tree age eight years at commencement of study) almost equidistant (50 m) from stations 2 and 3 and received only diffuse sunlight. Adults gathered on mud, decaying organic matter, wet sand and rocks at stations 1, 2 and 3, on cattle dung and mud at station 4 and on hoop pine foliage at station 5.

In April 1968, the number of adults found at stations 1–4 were counted at 15 minute intervals during daylight hours (0530–1800 h approximately) for seven consecutive days. Similar seven-day counts, conducted at three monthly intervals from July 1968 to April 1970,

were restricted to the period 0700–1100 h, when nearly all adult activity at the stations occurred. Additional counts were made simultaneously at stations 3 and 5 for three days in March 1969 to determine flight patterns between the open areas and the adjacent forest.

In March 1970, a simple experiment was conducted at stations 1, 2 and 4 to determine the relative attractiveness to *M. isodoxa* adults of five substances: fresh cattle dung, decomposing toad carrion, urine, honey-water (1:2 mixture) and water. Five white porcelain dining plates (19 cm diameter), each containing one of these substances, and two empty plates as controls were positioned at each station with a distance of 2 m or more between adjoining plates. The surface area of "attractant" on each plate was approximately 200 cm^2; the urine, honey-water and water were soaked onto pieces of cotton wool to provide a footing for the adults. These "attractants" were replenished daily and their relative positions at the stations rotated to ensure uniformity. Where possible, extraneous attractive material such as carrion and dung was removed from the vicinity of the stations at this time. Counts were made of the numbers of adults present at each plate at 15 minute intervals from 0700 h to 1100 h daily for seven consecutive days.

During the studies, bulb thermometers (0–100°C), Lambrect thermohygrographs® type 252 and solar radiation recorders® model R401 were used to measure temperature, relative humidity and solar radiation at the stations. Records of the number of sunshine hours each day were obtained from the meteorological station at the Bulolo Forestry College, approximately 3 km from the study area. Other details recorded included subjective assessments of cloud cover and rainfall intensity and observations on the feeding behavior of the males.

RESULTS

Flight Patterns

At the open sites (stations 1–4) the adults were predominantly males, and they displayed a similar daily flight behavior with little variation. They first appeared at the stations at approximately 0700 h, numbers reaching a peak between 0800–0915 h and declining rapidly thereafter so that by 1030 h few remained at the stations (Fig. 2). Within the plantations, adults resting overnight on hoop pine foliage became active between 0600–0630 h and began moving to the feeding areas. Few adults were seen within the plantations between 0800–0900 h each day. Counts at stations 3 and 5 showed that, as the number of adults along the stream decreased after 0900 h, numbers within the plantations increased, reaching a peak at approximately the same time

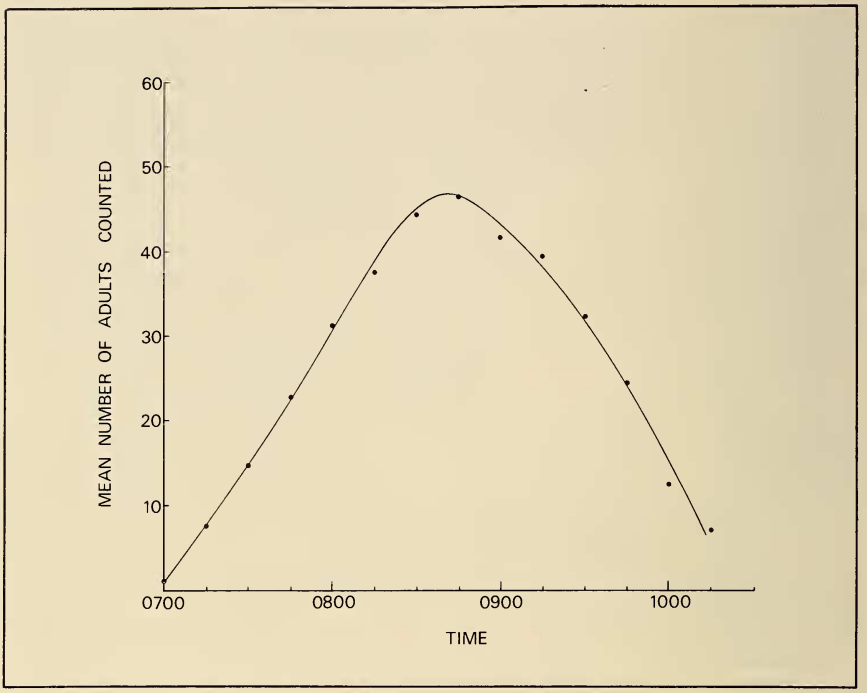

FIG. 2. Typical daily flight pattern of male *M. isodoxa* at feeding sites in the open at Bulolo. Means for station 1 are shown for 58 days of observation.

that the last adults left the stream (Fig. 3). Females observed at blossoms adjacent to the study area continued to feed for some time after the last males had been recorded at the stations and returned to the plantations towards 1200 h. Both sexes tended to congregate for a time on foliage of hoop pine trees along the margins before dispersing deeper into the plantation.

Field observations suggested that adult activity at the stations was greater on warm, sunny days, and population peaks occurred earlier in the morning than on cool, overcast days. For example, during counts at station 2 on 29 March 1969 in cool, overcast conditions (22.2–24.8°C), numbers of moths reached a peak of 66 at 0915 h. During counts at the same station four days later in warmer, sunny weather (22.7–27.8°C), numbers reached a peak of 160 at 0745 h. However, there were some cool, overcast days when large numbers of moths and early population peaks were recorded and some hot, sunny days when low numbers and late peaks occurred.

At all stations most population peaks (163 or 72% of a total of 225

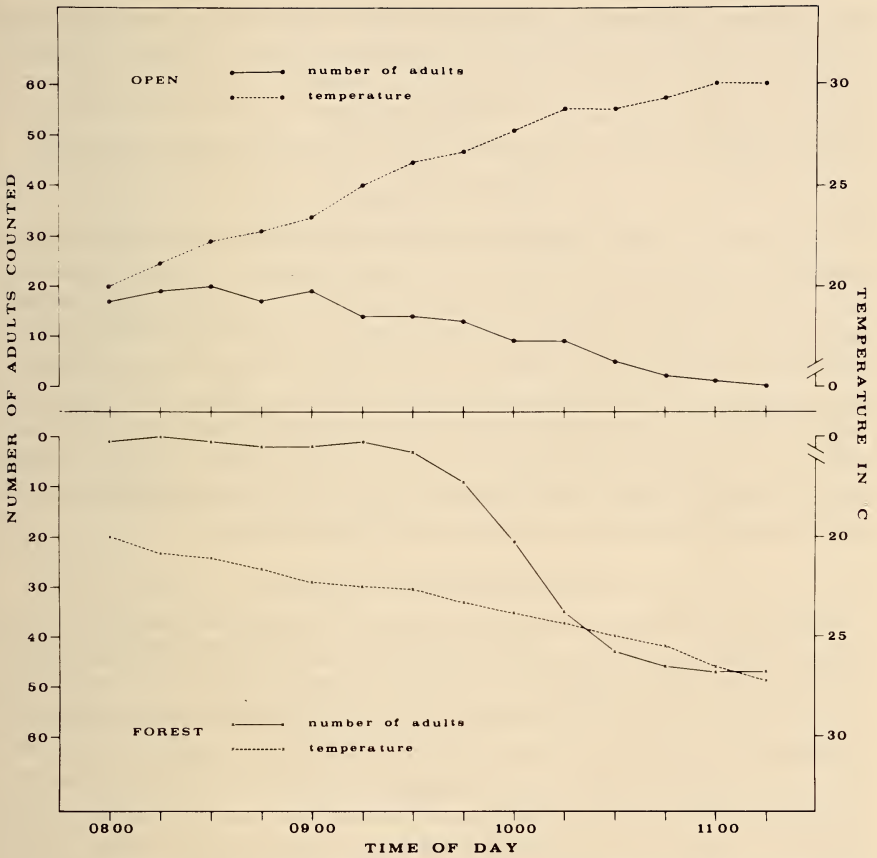

FIG. 3. Number of adults counted at station 3 (*open*) and station 5 (*forest*) between 0800–1115 h on 5 March 1969.

observations of peak time) occurred between 0800 and 0915 h each day. The earliest peak time recorded was 0730 h and the latest 1015 h. Of a total of 41 peaks recorded after 0915 h, 21 occurred at station 3 while, of the remainder, the numbers recorded at stations 1, 2 and 4 were six, five, and nine respectively. This again suggested that atmospheric conditions influenced flight activity of the moths, since station 3 received more shade during the morning than did the other three stations. However, peak time of activity at station 3 was not consistently later than, and in a few instances preceded peak times at the other stations.

When the data was subjected to stepwise multiple regression analysis, no direct relationship was found between adult flight behavior

and climatic conditions. The total number of adults (for any particular day) and peak time of activity (time during any particular day at which numbers reached their peak) varied at random. No definite seasonal effect was observed in the numbers of adults counted during the seven-day study periods in January, April, July and October each year.

Food Preferences

The total numbers of adults counted at all stations during the study period on dead toad, dung, urine, honey-water, water and controls were 1237, 633, 203, 52, 37 and 14 respectively. Analysis of variance showed a significant difference at the 1% level between the numbers of adults counted at the different "attractants." There was no significant difference at the 5% level between station replications. Numbers counted on toad and dung differed significantly from each other and from the remaining "attractants" (LSD = 135.7). Although some adults fed on wet sand and mud away from the plates, their numbers were much fewer than those recorded at toad and dung.

Feeding Behavior of Males

Males greatly outnumbered females in collections made on wet sand, mud, animal dung and carrion at Bulolo (Wylie, 1974b). Many of these moths appeared to be recently emerged; their wing and body scales were intact and there was no sign of the wear usually apparent on older insects. They probed and fed (with the proboscis extended) at moist sand and mud along stream and puddle margins, and occasionally at moss on rocks and at stream debris, not at the free water itself. On very wet ground the moths perched on the edge of dry pebbles and probed at the mud below. Several fed at patches of ground moistened by human urine and some were attracted to human sweat on both clothes and body. Males also fed on floral nectar and, in the laboratory, on a honey-water solution. When feeding, the males were remarkably docile and were easily captured by hand.

Large numbers of males fed commonly at cattle dung and toad (*Bufo marinus*) carrion. Fresh dung was preferred to dry, but toads dead for at least a day and beginning to decompose appeared more attractive than recently killed or dry material. A number of moths observed at dry dung and dry toad carcasses exuded a drop of liquid from the anus and imbibed from the moistened surface. This behavior among Lepidoptera has previously been regarded as a habit confined to the Hesperiidae (Norris, 1936).

It is interesting to note that while male *M. isodoxa* feed at the dead bodies of *B. marinus*, they are themselves prey to the toad, as evidenced in the laboratory when a supposedly dead toad revived among

captive moths, and in the field, when males attracted to a dead toad in a culvert were eaten by other toads sheltering in the culvert.

DISCUSSION

There are few references in the literature to adult behavior of *Milionia* species. De Mesa (1934, 1938) records daily flight patterns similar to those of *M. isodoxa* for adults of the pine-needle measuring worm *Milionia coronifera* Swinhoe at Baguio in the Philippines. He notes that adult *M. coronifera* migrate to the flowering plants between 0600–0900 h, returning to the pine forests (*Pinus kesiya*) between 0900–1000 h each day. A second migration to blossoms occurs at 1700 h, and the moths rest at night in the crowns of the pine trees. At Bulolo there was no conspicuous late afternoon migration of *M. isodoxa*, although occasional moths were seen in flight along the roads at this time. In Sumatra, Mangundikoro and Depari (1958) mention only that moths of *Milionia basalis* Walker, a defoliator of *Pinus merkusii*, were frequently observed in flight during the day along the fringes of the plantations.

Eight species of *Milionia*, in addition to *M. isodoxa*, have been recorded from the Bulolo/Wau area. Two of these species, *M. dohertyi* Rothschild and *M. mediofasciata* Rothschild, are predominantly night-flying and regularly appear in collections at light. No daylight flight has been observed for moths of *M. dohertyi* (J. J. H. Szent-Ivany, pers. comm.) but a single *M. mediofasciata* male was recorded at station 1 at 0745 h during counts in January 1970. Both *M. callima* Rothschild & Jordan and *M. grandis* adults were observed in morning flight near the plantations, and *M. grandis* was also collected at light. The remaining four species, *M.* ? *aglaia* Rothschild & Jordan, *M. aroensis* Rothschild, *M. diva* Rothschild & Jordan and *M. paradesia* Jordan, were captured in flight during the day along mountain streams (1700 m) near Wau (P. Shanahan, pers. comm.).

Although the daily flight patterns of adult *M. isodoxa* at Bulolo, involving a movement from the plantations to obtain food and a subsequent return to mate and egg-lay, are established, the factors influencing the timing of these flights to and from the feeding areas remain unknown. Initial observations suggested that either temperature or solar radiation may be important in determining when numbers peak and when the moths begin to leave the stations. These factors could act directly by heating the body of the insect, or indirectly by drying out the food and rendering it less attractive. However, this does not explain the sometimes early disappearance of moths from shaded areas along creeks or roads or the rapid decline in numbers at the stations on some cool, overcast days. Similarly, relative humidity or saturation

deficiency must be of minor importance when considering a stream environment even on the hottest days.

Rainfall may deter or delay the flight of moths to the stations on certain days. It may also affect the numbers of moths recorded at the stations on subsequent fine days by (i) increasing the number of alternative feeding sites and thus decreasing totals at the stations or (ii) increasing the attractiveness of the stations as feeding sites and thus increasing total numbers recorded. However, it would be unlikely to affect flight times on these fine days.

Many records in the literature indicate that atmospheric conditions are important in influencing flight patterns of puddle-frequenting species (see Norris, 1936). However, because of anomalies such as those described above for *M. isodoxa*, a simple relationship appears unlikely.

Norris (1936), in an extensive review of the feeding habits of Lepidoptera, lists many species which feed at puddle margins, dung and carrion, including some Geometridae. Nearly all records show a great preponderance of males at sites similar to that found for *M. isodoxa* at Bulolo. She notes that, as with *M. isodoxa*, many species drank at puddle and riverside sites contaminated by animal excreta even when cleaner water was abundantly available and observes that practically all water-drinking may be primarily due to the attraction of such contaminants. Downes (1973) concurs, regarding puddles as areas of concentration of organic debris and solutes and further suggests that puddles, dung and carrion represent successively higher levels of the same stimuli. Observations of *M. isodoxa* at Bulolo support this view, toad carrion and dung in that order being preferred to wet sand and mud.

With respect to carrion and dung and perhaps other foods, there appear to be different degrees or stages of attractiveness. For example, Payne and King (1969) list 21 species of Lepidoptera attracted to pig carrion at Clemson, South Carolina, 17 of which (including three geometrids) preferred the carrion in a state of advanced decay. At Bulolo, *M. isodoxa* preferred toads which were actively decomposing to freshly killed or dried material, and more were attracted to fresh dung than to dry.

The nutritional requirement for insects that is satisfied by probing at puddles, dung and carrion is little known (Downes, 1973; Norris, 1936). In Diptera, protein is required by some species for reproductive development in females. For example, the females of the sheep blowfly, *Lucilia cuprina* (Wiedemann), require protein to mature each cycle of oocytes (Williams et al., 1977), and in many species of mosquitoes the number of oocytes that reach maturity is related to the

amount and type of blood that the females ingest (Shelton, 1972). In Lepidoptera, males of most species are seen puddling much more often than females. Puddling behavior probably permits them to take in nutrients above those provided by larval nutrition or available from nectar, and both organic and inorganic solutes may be sought (Downes, 1973; Arms et al., 1974).

The tendency for many puddle-frequenting Lepidoptera to gather in closely packed groups at the feeding sites is often mentioned in the literature (Norris, 1936). Collenette and Talbot (1928) show how feeding aggregations of *Catopsilia* (Pieridae) are built up by visual recognition of the already established individuals. Downes (1973) however, suggests that odor may be more important than visual stimuli for some species, although visual responses may also occur. In the case of *M. isodoxa* at Bulolo, odor seems to be of major importance in the formation of feeding groups. The most striking aggregations of moths are seen on carrion and dung, while they tend to feed more individually at lightly contaminated and less odorous areas such as stream margins. However, several males, on arriving at the stations, flew directly to join groups feeding on toad and dung, a behavior which suggests some visual response.

The described flight behavior of *M. isodoxa* adults may influence the distribution of larval populations of the insect in hoop pine areas. At Bulolo, Wylie (1982) showed that *M. isodoxa* larvae were more abundant on host trees in areas adjacent to a stream or soak than on trees in drier areas of the plantations. This was attributed, in part, to a presumed higher frequency of egg-laying where adults congregate on trees close to the feeding sites.

ACKNOWLEDGMENTS

I thank Dr. B. Gray, Beerwah, Queensland and Drs. G. Hooper and T. Woodward, University of Queensland, Brisbane, for their helpful advice during the study and in the preparation of this paper. I thank Dr. D. Sands, C.S.I.R.O., Brisbane for his review of the final manuscript. Appreciation is expressed to the staff of the Entomology Section, Bulolo, who assisted in the field studies. I am grateful to Mr. M. Nester, Department of Forestry, Brisbane, for his assistance in the statistical analysis and Mrs. J. Hockey and Mrs. D. Toomey for typing the manuscript.

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